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FOR

WIRELESS COMMUNICATION SYSTEM WITH A SUPPLEMENTAL COMMUNICATION SUB-SYSTEM

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WIRELESS COMMUNICATION SYSTEM WITH A SUPPLEMENTAL COMMUNICATION SUB-SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to wireless communication systems.

Description of the Related Art

Wireless communication systems are extensively used to provide communication services to a wide array of users. A typical wireless communication system includes a plurality of base stations (BSs), each BS configured to communicate with mobile stations located in proximity to that BS. Base stations are appropriately spaced to create a communication structure, in which each BS covers a certain geographical area (cell). A typical BS has an antenna system coupled to a radio frequency (RF) transceiver to provide wireless links with mobile stations. In addition, each BS has an interface system to provide a wire-line link with a mobile services switching center (MSC). The MSC controls the operation of base stations in the assigned area and serves as a gateway between those base stations and the public switched telephone network (PSTN).

Actual shapes and sizes of cells in the communication structure are complex functions of the transmitted RF power, the terrain, the man-made environment, and the required quality of communication and user capacity. As a result, relatively often, a cell has a non-contractible shape characterized by the presence of one or more blind spots, i.e., locations at which service is (temporarily or permanently) unavailable to user (where the term "contractible" is a term of topological arts meaning "shrinkable to a point within itself"). For example, blind spots are often present in building interiors due to the substantial RF power attenuation by metal parts in the building structure.

SUMMARY OF THE INVENTION

Problems in the prior art are addressed, in accordance with the principles of the present invention, by a wireless communication system having primary and supplemental communication sub-systems. The primary communication sub-system includes a plurality of base stations and a mobile services switching center (MSC) of the prior art. The supplemental communication sub-system includes one or more supplemental transceiver units (STUs) controlled by a supplemental switching center (SSC) having access to a public switched telephone network (PSTN). Each STU has a primary function and, in addition, is adapted to support (i) a wireless communication link with at least one mobile station and (ii) a wire-line communication link with the SSC. In one embodiment, an STU of the invention has a conventional TV receiver and a TV screen whose

primary function is to receive and display television programs supplied over a cable network. In addition, the STU has an RF transceiver designed to support a wireless communication link with N mobile stations and an interface designed to support, over the same cable network used for transmitting the television signals, a cable communication link with a service distribution node of the cable service provider, which node is configured to perform the functions of an SSC. Advantageously, a wireless communication system of the invention may have a smaller area affected by blind spots compared to that in prior-art systems. In addition, the supplemental communication sub-system provides additional communication capacity, which may be utilized to improve performance, for example, when call volume processed by the primary communication sub-system becomes relatively high.

According to one embodiment, the present invention is a method of transmitting communication signals corresponding to a mobile station in a wireless communication system, the method comprising: (A) selecting one of a primary communication sub-system and a supplemental communication sub-system to carry the communication signals for the mobile station; and (B) transmitting the communication signals for the mobile station via the selected communication sub-system, wherein: the wireless communication system includes the primary and supplemental communication sub-systems; the supplemental communication sub-system includes one or more STUs connected to an SSC; the SSC has access to a PSTN and is adapted to control operation of the one or more STUs; and each STU has a primary function and is further adapted to support (i) a wireless communication link with at least one mobile station and (ii) a wire-line communication link with the SSC.

According to another embodiment, the present invention is an apparatus for use in a wireless communication system providing service to mobile stations, the apparatus comprising: a radio-frequency transceiver (RFT) adapted to support a wireless communication link with at least one mobile station; and an interface adapted to support a wire-line communication link with an SSC having access to a PSTN, wherein: the apparatus has a primary function and is adapted to be controlled by the SSC; and the wireless communication system includes the SSC.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a diagram of a prior-art wireless communication system;

Fig. 2 shows a diagram of a wireless communication system according to one embodiment of the present invention; and

Fig. 3 shows a block diagram of a supplemental transceiver unit (STU) that can be used in the system of Fig. 2 according to one embodiment of the present invention.

DETAILED DESCRIPTION

Reference herein to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment can be included in at least one embodiment of the invention. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments.

Fig. 1 shows a diagram of a prior-art wireless communication system **100**. More specifically, system **100** includes a plurality of base stations **104** communicating with one or more mobile stations **102**. Each base station (BS) **104** serves a cell **106** illustratively indicated in Fig. 1 by a hexagon. BS **104** is designed to provide (i) wireless links with mobile stations located within cell **106** and (ii) a wire-line link with a mobile services switching center (MSC) **108**. MSC **108** is designed to control the operation of base stations **104** connected to the MSC. For example, MSC **108** provides the functions needed to track and maintain communication with each mobile station (MS) **102**, including registration, authentication, location updating, hand-offs, call routing, etc. In addition, MSC **108** serves as a gateway to a public switched telephone network (PSTN) **110**. Although only three cells **106a-c** served by the corresponding three base stations **104a-c** are shown in Fig. 1, wireless communication system **100** may include hundreds of cells **106** served by a corresponding number of base stations **104** and more than one MSC **108**.

When a particular MS **102** is turned on or has just moved into the area served by system **100**, that MS transmits a registration request containing its identification information. If a single BS **104** detects the registration request, that particular BS is assigned by MSC **108** to handle transmissions for MS **102**. If more than one BS **104** detects the registration request, MSC **108** selects one particular BS, e.g., based on the detected signal strength, to handle those transmissions. When MS **102** moves within the coverage area of system **100**, the MS may re-register as known in the art and a different BS **104** may be assigned by MSC **108** to handle transmissions for the MS.

The following is a brief description of representative steps taking place when MS **102** places or receives a call over system **100**. When MS **102** attempts to place a call to a telephone **132** connected to PSTN **110**, the MS sends a call initiation request containing the telephone number of telephone **132** to the corresponding BS **104**. BS **104** forwards the request to MSC **108**, which validates the request and uses the telephone number to make a connection via PSTN **108** to telephone **132**. To receive incoming calls, MS **102** continually scans for paging signals from the corresponding BS **104**. When MSC **108** receives via PSTN **110** a request from telephone **132** for connection with MS **102**, the MSC forwards the request to the appropriate BS **104**, which then pages the MS. After MS **102** acknowledges the page, MSC **108** routes the call from telephone **132** via the corresponding BS **104** to the MS.

To connect two mobile stations **102**, MSC **108** receives, e.g., as described above, a request from a first (i.e., calling) MS **102**. When the requested (i.e., called) MS **102** is located in the area controlled by MSC **108**, the MSC routes the call to that MS, e.g., as described above, but without connecting to PSTN **110**. However, when the called MS is located in the area controlled by a different MSC, MSC **108** connects to that other MSC via PSTN **110**. The MSC corresponding to the called MS then routes the call to that MS, e.g., as already described above for a call originating from telephone **132**.

As indicated in the background section, one problem with system **100** is that each cell **106** might have one or more blind spots, e.g., inside buildings, where signals from the corresponding BS **104** are substantially blocked from reaching mobile stations located within those blind spots. It is therefore desirable to have a wireless communication system, in which the occurrence of blind spots is reduced.

Fig. 2 shows a diagram of a wireless communication system **200** according to one embodiment of the present invention. System **200** has two superimposed communication sub-systems: (1) a primary communication sub-system comprising a plurality of cells **206** and (2) a supplemental communication sub-system comprising a plurality of cells **226**. In Fig. 2, the primary and supplemental communication sub-systems are illustratively shown as having cells **206a-g** and **226a-d**, respectively. Cell **206a** is indicated by a hexagon; cells **206b-g** are shown only partially; and each of cells **226** is indicated by a circle. In a different embodiment, system **200** may have a different number of cells **206** and **226** having different shapes.

The primary communication sub-system of system **200** is analogous to the communication structure of system **100** (Fig. 1). For example, each cell **206** of system **200** is similar to cell **106** of system **100** and is served by a corresponding BS **204** connected to an MSC **208**, where BS **204** and MSC **208** perform functions analogous to those of BS **104** and MSC **108**, respectively. Hence, using the primary communication sub-system in system **200**, an MS **202** can establish a communication link with another MS **202** or a wired telephone **232** connected to a PSTN **210** substantially as described above for MS **102** in system **100**.

The supplemental communication sub-system in system **200** is novel and will be described in more detail below. Each cell **226** of the supplemental communication sub-system represents the coverage area of a corresponding supplemental transceiver unit (STU) **224**, which can establish and maintain a wireless communication link with at least one MS **202** located within that coverage area. Although Fig. 2 illustratively shows four STUs **224a-d** in cell **206a**, in a different embodiment, system **200** may have a different number of STUs **224** distributed over any selected number of cells **206**. In addition, system **200** may have STUs **224** located outside cells **206**. The superposition of cells **226** may or may not form a contiguous geometric shape; different cells **226** may or may not overlap with each other; and each cell **226** may partially overlap with more than one cell **206**.

In a preferred embodiment, STU **224** is an "appliance," which has a particular primary function and is connected to a wire-line network **230**. In addition, STU **224** incorporates an RF transceiver designed to establish and support a wireless link with at least one MS **202** using a suitable standard such as, for example, IS-54 (TDMA), IS-95 (CDMA), CDMA 2000, W-CDMA, GMS, AMPS, IEEE 802.11, or Blue Tooth, or a proprietary RF interface. STU **224** preferably has a coverage area (i.e., cell **226**) whose linear dimension is about 10 to 100 meters. For example, depending on the environment and the power of the RF transceiver in STU **224**, cell **226** could be a room in a building or a circle with the diameter of 100 m around a farmhouse.

Network **230** connects different STUs **224** to a supplemental switching center (SSC) **228**. The bandwidth of network **230** depends on the primary function of STUs **224** and can be fixed or variable with time. In a preferred embodiment, SSC **228** supports the primary function of STUs **224** and, in addition, is designed to provide the functions needed to track and maintain communication via those STUs with mobile stations **202** in cells **226**. The latter functions of SSC **228** are similar to those of MSC **208** and include registration, authentication, location updating, hand-offs, and call routing. Similar to MSC **208**, SSC **228** serves as a gateway to PSTN **210**. MSC **208** and SSC **228** maintain a service link **234**, which is used to coordinate handling of transmissions for mobile stations **202** in system **200**.

When MS **202** is located within cell **206**, but outside of cell **226**, the MS registers with MSC **208** only, e.g., as described above for system **100**. Similarly, when MS **202** is located within cell **226**, but outside or in a blind spot of cell **206**, the MS registers with SSC **228** only. Such registration may be analogous to the registration with MSC **208**. For example, if a single STU **224** detects a registration request from MS **202**, then that particular STU is assigned by SSC **228** to handle transmissions for the MS. If more than one STU **224** detects the registration request, SSC **228** selects one particular STU, e.g., based on the detected signal strength, and assigns that STU to handle those transmissions.

When MS **202** is located within both cell **206** and cell **226**, the MS registers with both MSC **208** and SSC **228**, e.g., as described above. Then, using service link **234**, MSC **208** and SSC **228** determine which of them will handle transmissions for MS **202**. In one configuration, whenever MS **202** is registered with SSC **228**, the SSC is selected to handle transmissions for the MS. One purpose of this transmission-handling selection is to reduce the communication burden on MSC **208** and BSs **204**. In another configuration, either MSC **208** or SSC **228** may be selected, e.g., based on the respective signal strengths detected by the corresponding BS **204** and STU **224**. When MS **202** moves within the coverage area of system **200**, the MS may re-register and a different transmission-handling selection may be made, e.g., as described above.

The following is a brief description of representative steps taking place when MS **202** places or receives a call over system **200**. When MS **202** attempts to place a call to a telephone **232**

connected to PSTN **210**, the MS sends a call initiation request containing the telephone number of telephone **232** to the corresponding BS **204** and/or STU **224**. Depending on the selection made during the registration, either BS **204** or STU **224** acknowledges the request. For example, when SSC **228** is selected to handle transmissions for MS **202**, STU **224** acknowledges the request and forwards it to the SSC, which validates the request and uses the telephone number to make a connection via PSTN **208** to telephone **232**. Similarly, when MSC **208** is selected to handle transmissions for MS **202**, BS **204** acknowledges the request and forwards it to the MSC, which then makes the corresponding connection via PSTN **208** to telephone **232**.

To receive incoming calls, MS **202** continually scans for paging signals from the corresponding BS **204** and STU **224**. Depending on the selection made during the registration, either MSC **208** or SSC **228** is configured to handle incoming calls for MS **202**. For example, when SSC **228** is selected to handle transmissions for MS **202**, the SSC receives via PSTN **210** a connection request from telephone **232** and forwards the request to the appropriate STU **224**, which then pages the MS. After MS **202** acknowledges the page, SSC **228** routes the call from telephone **232** via that STU **224** to the MS. Similarly, when MSC **208** is selected to handle transmissions for MS **202**, the MSC receives via PSTN **210** the connection request from telephone **232** and forwards the request to the appropriate BS **204**, which then pages the MS. After MS **202** acknowledges the page, MSC **228** routes the call from telephone **232** via that BS **204** to the MS.

To connect two mobile stations **202** over system **200**, for each of those mobile stations, it is appropriately selected, e.g., as described above, which of MSC **208** and SSC **228** will handle transmissions for the MS. Then, depending on the particular combination of transmission handling selections, calls are routed over system **200** as indicated in Table 1, where indices I and II denote, respectively, first and second mobile stations **202** and their corresponding base stations **204** and/or STUs **224**. Either MS_I or MS_{II} may be the calling station.

Table 1. Call Routing between Two Mobile Stations **202** in System **200**

	Transmission Handling Selection		
MS_I MS_{II}	MSC MSC	MSC SSC	SSC SSC
Call Routing	MS_I – BS_I – MSC – BS_{II} – MS_{II}	MS_I – BS_I – MSC – PSTN – SSC – STU_{II} – MS_{II}	MS_I – STU_I –SSC – STU_{II} – MS_{II}

For example, when MS_{II} is the calling station and the transmission handling selections are made in accordance with the middle column of the corresponding section in Table 1, a call from MS_{II} to MS_I is routed as follows: MS_{II} – STU_{II} – SSC – PSTN – MSC – BS_I –MS_I.

Alternatively, service link **234** may be used to bypass PSTN **210** while connecting MSC **208** and SSC **228**. In this configuration, handoff of MS **202** between MSC **208** and SSC **228** may be implemented similar to inter-MSC handoff in prior-art systems.

In a different embodiment, system **200** may have more than one MSC **208** and/or more than one SSC **208**, each connected to PSTN **210**. Such multiple MSCs and SSCs have appropriate communication links similar to service link **234**, which are used for performing call routing and hand-off functions. Table 2 indicates call routing in such system, where indices I and II, in addition to denoting first and second mobile stations **202** and their respective base stations **204** and STUs **224**, also denote the corresponding different MSCs and/or SSCs.

Table 2. Call Routing between Two Mobile Stations **202** in an Embodiment of System **200** Having More Than One MSC **208** and/or More Than One SSC **228**

	Transmission Handling Selection		
MS_I MS_{II}	MSC_I MSC_{II}	MSC_I SSC_{II}	SSC_I SSC_{II}
Call Routing	MS_I – BS_I – MSC_I – PSTN – MSC_{II} – BS_{II} – MS_{II}	MS_I – BS_I – MSC_I – PSTN – SSC_{II} – STU_{II} – MS_{II}	MS_I – STU_I –SSC_I – PSTN – SSC_{II} – STU_{II} – MS_{II}

For example, when MS_I is the calling station and the transmission handling selections are made in accordance with the last column of the corresponding section in Table 2, a call from MS_I to MS_{II} is routed as follows: MS_I – STU_I –SSC_I – PSTN – SSC_{II} – STU_{II} – MS_{II}.

Fig. 3 shows a block diagram of an STU **324** that can be used as STU **224** in system **200** according to one embodiment of the present invention. More specifically, STU **324** is a novel TV set connected to network **230**, which is a TV cable network. As such STU **324** has a conventional TV receiver **302** and a TV screen/speakers **304** whose primary function is to receive and display TV programs transmitted over network **230**. In addition, STU **324** has an antenna **306** coupled to an RF transceiver (RFT) **308** designed to support a wireless communication link with N mobile stations **202**, where N is an integer greater than 0. As such, transceiver **308** supports the appropriate number of communication channels in a selected frequency band. STU **328** also has an interface designed to support a wire-line communication link with SSC **228** (Fig. 2), which, in this case, is a service distribution node of the TV cable service provider. In one implementation, the interface includes a

multiplexer/de-multiplexer (MUX/DMUX) **310** and a cable modem **312**. Up to N data streams corresponding to the transmissions received by RFT **308** from up to N mobile stations **202** are multiplexed using MUX/DMUX **310**, the output of which is applied to modem **312** coupled to network **230**. Using one or more upstream cable channels assigned by SSC **228**, modem **312** transfers the data over network **230** to the SSC. Similarly, using one or more downstream cable channels assigned by SSC **228**, modem **312** receives from the SSC signals corresponding to transmissions directed to the up to N mobile stations. The data stream generated by modem **312** is appropriately de-multiplexed into up to N individual data streams using MUX/DMUX **310**, each individual data stream corresponding to a particular MS **202**. These up to N data streams are then applied to RFT **308** for wireless transmission to the mobile stations.

Since TV cable service is typically available inside buildings where blind spots often occur, system **200** configured with STUs **324** may advantageously be able to provide service to mobile stations therein, thereby reducing the area affected by blind spots compared to that in prior-art wireless communication system **100**. In addition, due to the presence of the supplemental communication sub-system, system **200** has additional communication capacity, which may be utilized to improve performance, for example, when call volume processed by a particular cell of the primary communication sub-system approaches the full capacity of the corresponding BS.

In alternative embodiments, the supplemental communication sub-system in system **200** may be based on different STU devices. For example, in one embodiment, STU **224** is a stationary radio set connected to a radio programming distribution network **230** and SSC **228** is a distribution node of the corresponding service provider. In another embodiment, STU **224** is a computer, network **230** is a local area network connected to the Internet, and SSC **228** is a node of an Internet service provider.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Although system **200** was described in reference to voice communications, it can also be configured to transmit data. The standard used for implementing a wireless communication link between STU **224** and MS **202** may or may not have a quality of service (QoS) provision. SSC **228** may not be directly connected to PSTN **210** and use link **234** to connect to the PSTN via MSC **208**. Various modifications of the described embodiments, as well as other embodiments of the invention, which are apparent to persons skilled in the art to which the invention pertains are deemed to lie within the principle and scope of the invention as expressed in the following claims.

Although the steps in the following method claims, if any, are recited in a particular sequence with corresponding labeling, unless the claim recitations otherwise imply a particular sequence for implementing some or all of those steps, those steps are not necessarily intended to be limited to being implemented in that particular sequence.